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Physico-chemical analysis of Logone River water at Moundou City in Southern Chad

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ABSTRACT

The physico-chemical parameters and some heavy metal concentrations in the Logone River water at Moundou City, Chad, are studied for two stations from July 2013 to December 2014, one upstream and another downstream of the city. Standard methods are used. A total of twenty-two physico-chemical parameters were determined by spectrophotometers showed clear seasonal variations of; BOD_5, COD, sulphate, phosphate, and nitrate, among the stations. The Moundou City wastewater negatively impacted the concentrations of physico-chemical parameters of Logone River water samples when compared with the World Health Organization (WHO) permissible limits. It was observed that the water quality parameters exceed the permissible limits downstream of the river:BOD_5 (198mg/l), COD (897 mg/l), MES (287 mg/l), F(1.87 mg/l), heavy metals Cr (0,934 mg/l), Fe (5,55 mg/l) Cu (0,294 mg/l), Pb (17 mg/l), As (0,894 mg/l), Mb (14,2 mg/l). This study shows that industrial discharge into Logone River seriously contributes to the pollution of the river at the level which poses health and environmental hazards to those using it in downstream for domestic and agricultural purposes.

Keywords: Heavy metals, river water pollution, physico-chemical properties, Logone river, Moundou, Chad.

INTRODUCTION

Rapid urbanization and industrial development during last decades have negatively affected the environment. Heavy metals contamination of rivers is one of the main problems in many fast growing cities because the maintenance of water quality and sanitation infrastructure do not follow the population and urbanization growth especially in developing countries (Sundaray et al., 2006; Karbassi et al., 2007; Akoto et al., 2008; Ahmad et al., 2010).Trace metals enter the rivers from variety of sources; they can be either natural or anthropogenic (Bem et al., 2003; Wong et al., 2003; Adaikpoh et al., 2005; Akoto et al., 2008). Usually, in unaffected environments, the concentration of most of the metals is very low and is mostly derived from the mineralogy and the weathering (Karbassi et al., 2008). Main anthropogenic sources of heavy metal contamination are mining, disposal of untreated and partially treated effluents contain toxic metals, as well as metal chelates from different industries and indiscriminate use of heavy metal-containing fertilizer and

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pesticides in agricultural fields (Amman et al., 2002; Nouri et al., 2006; Nouri et al., 2008). Metals enter into river water from industrial and urban areas through various ways such as soap, oil brewery, and abattoirs and food factories. A study of spatio-temporal variations in water quality of NullahAik-tributary of the river Chenab, Pakistan by Qadir et al. (2008) revealed that the quality of upstream water is better than that of downstream water. The information on water quality and pollution sources is important for implementation of sustainable water-use management strategies (Sarkar et al., 2007; Zhou et al., 2007; Bu et al., 2009).

Logone, is a major river in Chad. Its main pollution sources are industrial, notably chemical, agricultural, and textile. Most of these industries discharge their effluents directly into the Logone River without any treatment, causing pollution of the water. Tchoroun (2012) studied the industrial effluent impacts in the Logone River and came to the conclusion that degree of some metals were above the permissible limits. Pollution from everyday domestic use could also be taken into consideration, as many persons use fresh water and then discharge the wastewater into the river.

The objectives of the present study were (1) To investigate the main polluants and establish their seasonal physico-chemical variation for Logone River water at two different sampling stations (upstream and downstream); and (2) To study their seasonal correlation.

MATERIALS AND METHODS

Study area

Moundou straddles the Logone River, and is the most industrialized city of Chad. Moundou has breweries and factories that produce textiles, soap, vegetable oil (from cotton seed) and tobacco. There is also a factory for building agricultural machines. All of these factories have been operating for many years.

We have the following water use information about the above mentioned factories. The textile industry discharges approximately 14 m^3/h of wastewater into the Logone River; the brewery discharges about 22 m^3/h; and the vegetable oil factory discharges about 0,17 m^3/h.

This study was conducted during the following period: July 2013, May 2014 and December 2014 at two different selected sampling sites along the Logone River upstream and downstream of the city of Moundou (Figure 1). Metal concentration in river water from upstream to downstream is illustrated in Tables 2, 3 and 4.

Water sampling and preservation

The water samples for this study were collected from upstream and downstream stations of the river in 250 mL polyethylene bottles, previously cleaned by detergent and rinsed with sampled water three times, and filled to the brim at depth less than one meter. The exact locations were recorded using the Global Positioning System (GPS). Some parameters were measured *in situ* (pH, Conductivity, Dissolved Oxygen, temperature). The samples were labeled and stored at 4 °C, then transported to laboratory for analysis. In this study, the water quality parameters: pH, Temperature, DO, BOD, COD, and Nitrates, Nitrites, Phosphate, Sulphate, heavy metals like Fe, Cu, Mn, Mb, Al, As, Zn, Cd, Pb and Ni were determined for the samples.

Physico-chemical analysis

The samples were collected and analyzed for temperature electrical conductivity, pH, and dissolved oxygen *in situ*. The analysis for the majority of the trace metals like chromium (Cr), cadmium (Cd), nickel (Ni), zinc (Zn), cupper (Cu), and iron (Fe) was done by Spectrophotometer 7100 water analysis leader UK, and DR/2400 and Cadmium was assayed by the method of molecular absorption spectrophotometer at 422 nm against reagent blank using a spectrophotometer (SHIMADZU UV-1700 PC). The determination of COD was made by digestion of potassium dichromate in a

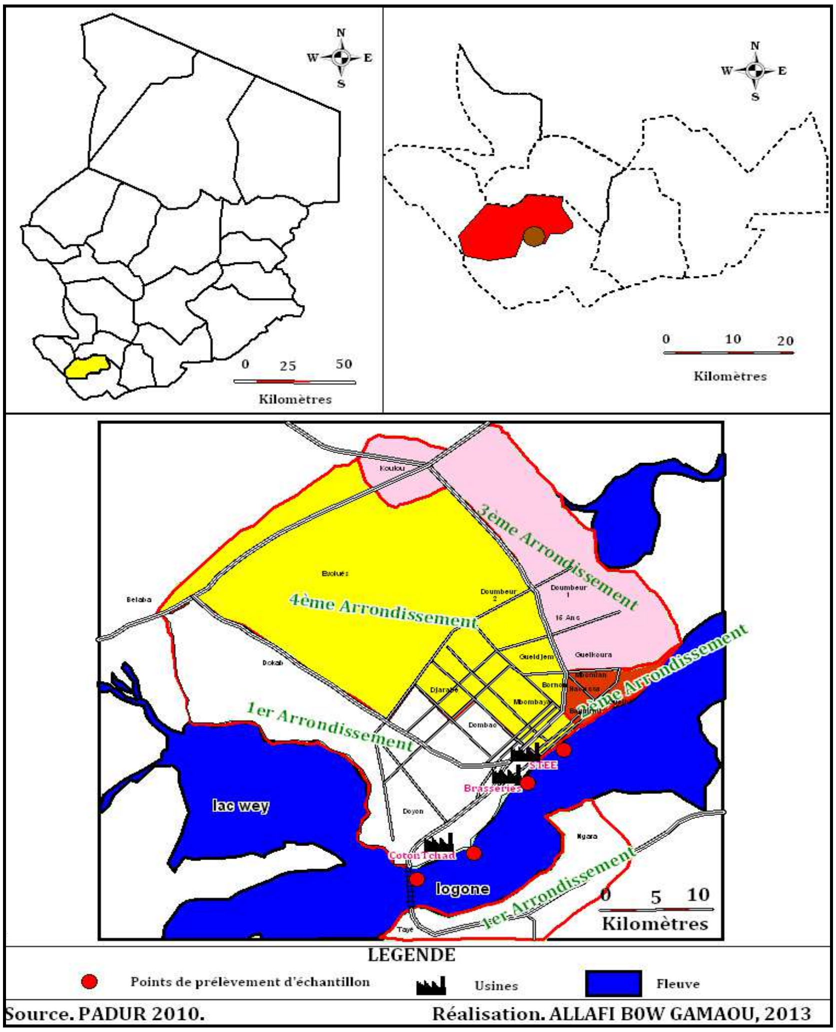

Figure 1: Location map of the study area.

DR/2400 HACH digester at 150 °C for 2 h and results were obtained on a DR/2400 spectrophotometer at a wave length of 620 nm (Hach, 1997). BOD5 was determined by the respirometric BOD Trak^{TM} 2000. A 160 mL, aliquot of each sample was introduced into a BOD bottle on the BOD Trak and incubated at 20 °C for 5 days. Readings were made on the screen of the BOD Trak (Hach, 1997).

Statistical analysis of data

In our present study, we determined the graphics using Microsoft Office Excel (Microsoft 2010). The data obtained were subjected to analysis for means, standard error and significance between the means at 95% probability level. These calculations were carried out using STATGRAPHICS 16.

RESULTS

The experimental data on heavy metal content and physico-chemical properties of water samples collected from Logone River flowing along the city of Moundou industrial area is presented in Tables 2, 3 and 4.

Potential of Hydrogen (pH)

pH is a measure of the acidity or alkalinity of water, and is one of the stable measurements. pH is a simple parameter but is extremely important, since most of the chemical reactions in aquatic environment are controlled by any change in its value. Anything either highly acidic or alkaline would kill marine life. In the present study, the average pH values of Logone River water was 6.27 in upstream and 7.66 downstream.

Temperature

Temperature is one of the most important ecological features. It controls behavioral characteristics of organisms, solubility of gases and salts in water. During this study, the temperature of the river water varies between 25.5 °C and 26.0 °C respectively at the upstream and downstream sampling locations. The mean temperature values of the water samples were not statistically different from each other ($p > 0.05$) and also fall within the normal temperature range supportive of good surface water quality which is 0 °C to 30 °C.

Electrical conductivity

The electrical conductivity (EC) is usually used for indicating the total concentration of charged ionic species in water. The most expedient to evaluate the salinity of water is to measure its electrical conductance. In this study, the electrical conductivity average ranges between 46.6 µS/cm in upstream in July and 67.6 µS/cm in downstream in May (Figure 2). From the table of analysis of variance ($p > 0,05$), there is not statically significant difference between upstream and downstream for Electrical Conductivity at the level of confidence of 95,0%.

Dissolved Oxygen

Dissolved oxygen (DO) has significant importance to the respiration activities of the aquatic organisms and effluents, and very low DO may have a negative impact on the sustainability of the rivers in the basin. In the present study, the DO ranges from 6.55 for upstream in rainy season to 7.21 mg/L for downstream during dry season followed by wet season (Figure 2). The mean DO values of Logone water for upstream and downstream samples were not significantly different ($p > 0.05$).

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Biological Oxygen Demand

In the present study, the biological oxygen demand (BOD values in Logone River ranged from 34 mg/l in upstream in December and 198 mg/l in downstream in dry season in May. The mean BOD values of Logone water for upstream and downstream samples were not significantly different ($p > 0.05$).

Chemical Oxygen Demand

The concentration of chemical oxygen demand (COD) reported in the present investigation was found to vary between 76.34 mg/l in upstream of Logone River water in December and 897 mg/l in downstream in July (rainy season). There was a clear seasonal variation in both BOD and COD; values increased from dry season to rainy season. The mean COD values of Logone water for upstream and downstream samples were not significantly different ($p > 0.05$).

Suspended Matters MES

The concentration of suspended matters MES range from 40 mg/l for upstream in May to 277 mg/l for downstream in rainy season (July).

Sulphates ions (SO4)

In this study the concentrations of sulphates value range from 10 mg/l in upstream in dry season and 56 mg/l in downstream in rainy season (July).

Phosphate ion (PO4)

Phosphate ion was not found in Logone River water during the investigation in most seasons. Only in December, a value of 0.001 mg/l was recorded for downstream.

Nitrates ion concentration (NO_3^-)

Nitrate values in Logone River water ranged from 0.14 mg/l in upstream in December (winter) and 46.0 mg/l in July rainy season. Sources of nitrate could be from oxidation of other forms of nitrogen compounds like ammonia and nitrite into nitrate. These values were below the permissible limit recommended by WHO (50 mg/l).There was a clear seasonal variation in both phosphate and nitrate; values increased from dry season to rainy season.

Fluoride

The fluoride concentration found in the water of Logone River between 1.16 mg/l in upstream and 1.87 mg/l in downstream in rainy season July. The average values were below the permissible limit recommended by World Health Organization (1,5 mg/l).

Chromium

The average concentration of Cr in water samples was found to vary between 0,04mg/L for upstream and 0,934 mg/L for downstream samples (Figure 4), which was higher than the permissible limit of 0.05 mg/L set by WHO.

Cadmium

Cadmium is contributed to surface waters through paints, pigments, glass enamel, deterioration of the galvanized pipes etc. The wear of studded tires has been identified as a source of Cd deposited on road surfaces. The average Cd content in water samples was found to vary between 0, 0124 mg/L in upstream and 0,183 mg/L in downstream of the river (Figure 4).

Nickel

The average Nickel content in the water samples during the study period was found to vary between 0.06 mg/L for downstream in rainy season and 0.95 mg/L for upstream of the river respectively in rainy season (Figure 4).

Zinc

In the present study, the average concentration of Zn in upstream and downstream water samples of Logone River was found to be 0,05 mg/L and 1,06 mg/L respectively (Figure 4). All concentrations were below the permissible limit of 5 mg/L recommended by World Health Organization (WHO).

Copper

Copper is a natural element which is widely distributed in soils, rocks and in rivers and the sea. Copper is widely used in society and yet is potentially quite toxic to life in rivers. The average concentration of Copper content in water samples was found to vary between 0,187 mg/L for upstream and 0,294 mg/L for downstream during all the three seasons (Figure 4).The observed downstream values were above the permissible limit of 0,2 mg/L set by WHO.

Lead

The average concentration of Pb in water samples was found to be 0.005 mg/L for upstream and 1,767 mg/L for downstream (Figure 5), which was much higher than the permissible limit for lead in drinking water (0.05 mg/L) according to WHO drinking water standards.

Iron

The maximum Fe concentrations recorded were 4,55 mg/l in downstream samples in July (rainy season). This may be attributed to soil-water interaction, especially from heavy rains. The minimum concentrations were found 0,334 mg/L for upstream samples in December (Figure 5). The mean Fe values of Logone water samples for upstream and downstream were not significantly different ($p > 0.05$).

Aluminum

No detectable levels of aluminum were found during this study, with the exception of one measurement of 0,014 mg/l in December.

Manganese

The element manganese is present in over 100 common salts and mineral complexes that are widely distributed in rocks, in soils, and on the floors of lakes and oceans. Industrial emissions containing manganese oxides are the principal source of manganese in the atmosphere. In the present study, no detectable levels of manganese were found, with the exception of one measurement of 0.001 mg/L in December (Figure 5).

Arsenic

In our study, the average concentration of arsenic in Logone River water during sampling periods were found 0.05 mg/L in July (rainy season) in upstream and 0.894 mg/L in downstream in December. The last value is highly above the permissible limit recommended by World Health Organization (WHO) which is 0.01 mg/l (Figure 5).

Molybdenum

In this study, the average concentration of molybdenum in the river water ranged between 8.034 mg/l in upstream of the river in December (winter) and 12.4 mg/l in downstream in May (dry season) as showed in (Figure 5).

Table 1: GPS position of sampling points.

Station	Latitude	Longitude
Upstream	05° 00 ′ 00 ″ N	15°00 00 ″ E
Downstream	08° 33 ′ 818″ N	16° 05 ′ 558 ″E

Table 2: Physico-chemical parameters of Logone River water at Moundou.

R1		R2	WHO
pH	6,27	7,18	6,5-85
Temperature (°C)	24,5	26,7	30 °C
Conductivity (µS/cm)	46,6	114	1000
Dissolved oxygen (O_2/mg/l)	6,55	7,16	5
MES (mg/l)	40	277	100
COD (mg O2/l)	76,34	897	90
DBO5 (mg O2/l	34	198	30

R1: Upstream of the river, R2: Downstream of the river

Table 3: Chemical parameters of Logone River in Moundou.

	F	NO3	SO4	PO4
Upstream (R1) (mg/l)	1,16	0,14	10	0,00
Downstream(R2) (mg/l)	1,18	46,0	56	0,001

Table 4: Heavy metal concentration in Logone River water at Moundou.

	Cr^{+6}	Cu	Fe	Zn	Cd	Ni	Pb	Mn	Mb
Upstream (R1) (mg/l)	0,04	0,187	0,34	0,05	0,124	0,34	0,008	0,00	8,04
Downstream(R2) (mg/l)	0,934	0,294	4,55	1,06	0,012	0,27	17,67	0,001	12,4
WHO limits (mg/l) (mg/l)	0,05	0,05	0,3	5	0,01	0,1	0,01	0,05	0,2

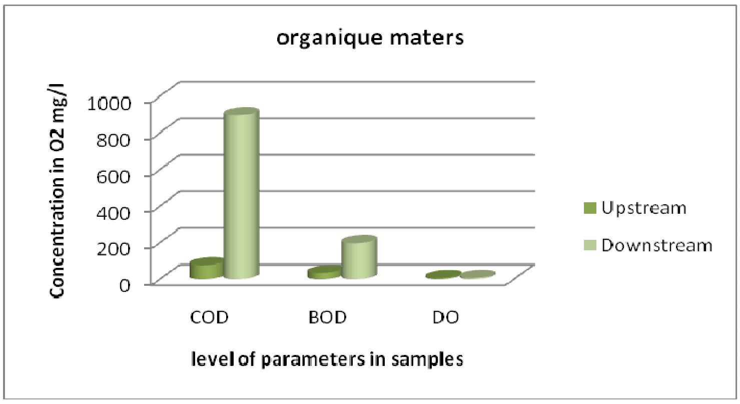

Figure 2: Variations in average physico-chemical parameters in water samples of Logone River.

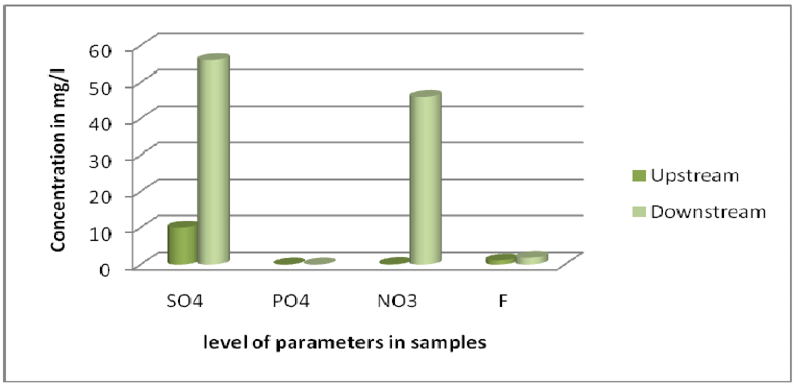

Figure 3: Variations in average of chemical parameter in water samples of Logone River in mg/l.

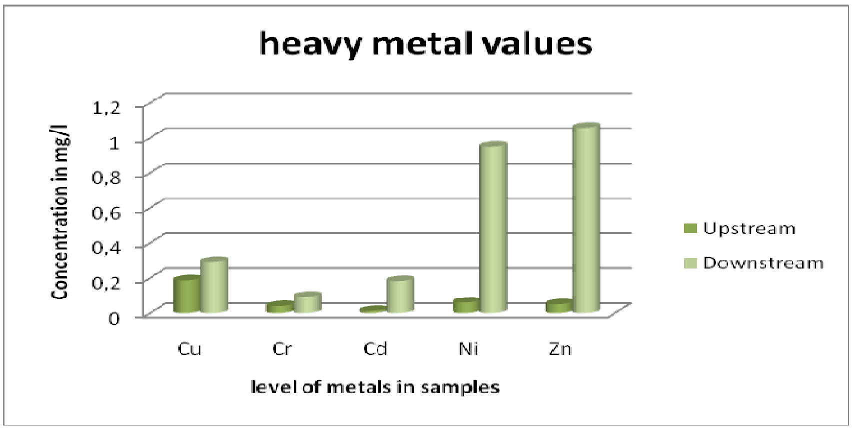

Figure 4: Variation in average concentration of toxic heavy metals in water samples of Logone River in Moundou.

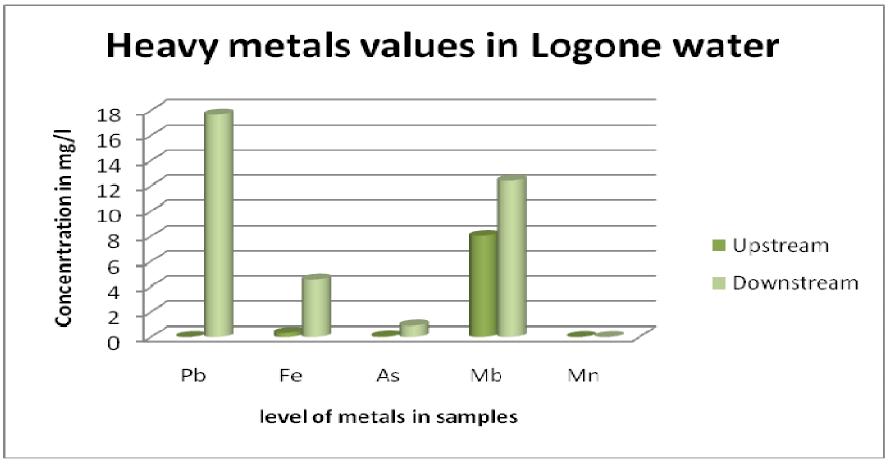

Figure 5: Variation in average concentration of toxic heavy metals in water samples of Logone River in Moundou.

DISCUSSION

Water quality is neither a static condition of a system, nor can it be defined by the measurement of only one parameter. There is a range of chemical, physical and biological components that affect water quality. These variables provide general indication of water pollution, whereas others enable a direct tracking of pollution sources (Pollution Environment Program.,2000).The pH of water samples collected from the river was slightly neutral (Table 1), and these values fall within the accepted range of 6.5–8.5 indicative of good water quality by WHO (WHO, 2002; Chapman., 1996). High pH of the River water may result in the reduction of heavy metal toxicity (Aktar et al., 2010).

The electrical conductivity (EC) and Dissolved Oxygen (DO) were under the permissible limits which is 100 µs/cm and 10 mg/l respectively. An adequate supply of dissolved oxygen is essential for the survival of aquatic organism (Dara, 2002).

Chemical Oxygen Demand is a measure of the oxidation of reduced chemicals in water it is commonly used to indirectly measure the amount of organic compounds in water (Kumar et al., 2011).The higher values of BOD and COD values are indicative of the presence of organic and inorganic pollutants, respectively. It may be due to discharges of oil and soap industry (owned by Cotontchad) and the brewery of Moundou. The mean BOD values exceeds the recommended maximum allowable concentration set by the European Union for good quality water for fisheries and other aquatic life, which is 3.0–6.0 mg/L (Chapman., 1996).It was reported that these parameters i.e., BOD and COD are responsible for odor and taste (Jones-Lee A 1993). The COD usually includes all, or most of the BOD as well as some other chemical demands. The significantly high mean COD (897mg/l) values also exceeded the acceptable concentrations for unpolluted surface water quality, which is 20 mg/L or less.

The high suspended matters MES value (287mg/l) occurs in rainy season, because of matter carried by runoff water. Dissolved SO_4^{-2}can be derived from the dissolution of SO_4minerals; oxidation of pyrite and other forms of reduced S; oxidation of organic sulfides in natural soil processes; and anthropogenic inputs, i.e. fertilizers (Grasby et al., 1997).

Some heavy metals concentrations in Logone water found during the present study were higher than the limit recommended by World Health Organization (WHO). The highest downstream concentration of chromium ion was 0.934 mg/L, which is higher than the permissible limit of 0.05mg/L set by WHO (APHA, 1995). The sources of emission of Cr in the surface waters are from municipal wastes, laundry chemicals, paints, leather, road runoff due to tire wear, corrosion of bushings, brake wires and radiators, etc. The high level of Fe (4.55 mg/l) in downstream during rainy season indicate that the composition of the soil region contain high level of iron. The presence of high concentration of Fe may increase the hazard of pathogenic organisms; since most of these organisms need Fe for their growth (Tiwana et al., 2005). The highest observed downstream concentration of Cu (0,294 mg/l) is higher than the recommended limit set by WHO (0,02mg/l). This may be attributed to domestic sewage and runoff from the extensive farmed area (Wu et al., 2008). Also, the highest downstream concentration of Cd in Logone water found (1,767 mg/l), which occurred in winter season, is higher than the limiting value of 0,01 mg/l recommended by WHO. The major source of Cd is coal combustion, metal industry and waste incineration (Brian and Bishop, 2009). The maximum downstream value of Ni was 0,95mg/L, which occurred in summer season. Ni can cause allergic reactionsm apart from being carcinogenic (McKenzic and Smythe, 1998).The highest Mn value was 0,001 mg/L, which occurred during winter season. Many key studies documenting the neurotoxic effects of Mn in children (Wasserman et al., 2006 ; Bouchard et al., 2007, 2011; Henn et al., 2011) and adults (Huang 2007; Perl and Olanow 2007 ; Lucchini et al., 2009) were published within the past 5 years. The highest downstream value of Zinc (1,06 mg/l) was obtained in rainy season. Zinc is one of the essential elements required for proper functioning of the body system (Raja and Venkatesan, 2010).

Conclusion

The present study data indicate that there is a significant pollution of Logone River water from industrial activity in the city of Moundou. The water quality of Logone River is deteriorated due to anthropogenic activities such as industrial use of water and discharge of untreated wastewater into the river. From this investigation, it can also be concluded that metal concentrations in dry season tend to be higher than in rainy season since the flow velocity of Logone River is decreased. As a result, the pollution load in dry season is more important when compared to other seasons.

The validity of the results obtained from Logone River water is supported by correlations found between the variables. The obtained BOD, COD, and some heavy metal values exceed the permissible limit of WHO, which shows that the contamination of water produced decline in DO of the water, which affects the sustainable life of plant and animals in the river. We recommend that strict measures should be taken, such as industrial wastewater and sewage water treatment, and to monitor their discharge into the environment to prevent the pollution of Logone River water.

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